4475 73299

SEARCH REQUEST FORM Scientific and Technical Information Center - EIC2800

Rev. 8/27/01 This is an experimental format -- Please give suggestions or comments to Jeff Harrison, CP4-9C18, 306-5429.

Date 8/14/02. Serial # ______ Priority Application Date ______

Your Name DALEI DONG. Examiner # ______

AU 2875 Phone ______ Room 6B37

In what format would you like your results? Paper is the default. PAPER DISK EMAIL

If submitting more than one search, please prioritize in order of need.

The EIC earcher normally will contact you before beginning a prior art search. If you would like to sit with a s archer for an interactive search, please notify one of the searchers.

Where have you searched so far on this case?

Circle: USPT DWPI EPO Abs JPO Abs IBM TDB

Other: ______

What relevant art have you found so far? Please attach pertinent citations or Information Disclosure Statements. ______

What types of references would you like? Please checkmark:

Primary Refs ___ Nonpatent Literature ___ Other ______

Secondary Refs ___ Foreign Patents ___

Teaching Refs ___

08-14-02 P02:48 OUT

What is the topic, such as the **novelty**, motivation, utility, or other specific facets defining the desired **focus** of this search? Please include the concepts, synonyms, keywords, acronyms, registry numbers, definitions, structures, strategies, and anything else that helps to describe the topic. Please attach a copy of the abstract and pertinent claims.

WHAT IS THE ELASTICITY OF ZIRCONIA AND SODIUM SILICATE AT 25°C.

Staff Use Only	Type of Search	Vendors
Searcher: Derrick Blalock	Structure (#) ___	STN ___
Searcher Phone: 306-0935	Bibliographic ___	Dialog ___
Searcher Location: STIC-EIC2800, CP4-9C18	Litigation ___	Questel/Orbit ___
Date Searcher Picked Up: 8/15/02	Fulltext ___	Lexis-Nexis ___
Date Completed: 8/15/02	Patent Family ___	WWW/Internet ✓
Searcher Prep/Rev Time: 0	Other ✓	Other ✓
Online Time: ~~200~~ 180		

Element Information: Thorium

Thorium

90	Atomic Number	90
Th	Atomic Weight	232.0381
232.0381	Electron Config.	2-2-6-2-6-10-2-6-10-14-2-6-10-0-2-6-2-2

Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

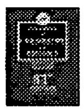
Mechanical Properties		Conditions		
		Phase	**Temp.** (K)	**Pressure** (Pa)
Density	11700 kg/m^3	Solid	298.15	0
Poisson Ratio	0.27	Solid		
Thermal Expansion Coefficient	1.100×10^{-5} /K	Solid	298.15	

Electrical Properties		Conditions	
		Temp. (K)	**Note**

Electrical Resistivity	1.300×10^{-7} Ω-m	273.15

Thermal Properties		**Conditions**	
		Temp. (K)	**Pressure** (Pa)
Melting Temperature	2023.15 K		101325
Boiling Temperature	5061.15 K		101325
Critical Temperature	14400 K		
Fusion Enthalpy	59.5 J/g	0	101325
Heat Capacity	113 J/kg-K	298.15	100000
Thermal Conductivity	54 W/m-K	300	101325

Download a Palm version of eFunda's periodic table!



CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

Palladium

46
Pd
106.42

Atomic Number	46
Atomic Weight	106.42
Electron Config.	2-2-6-2-6-10-2-6-10

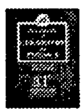
Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		**Conditions**		
		Phase	**Temp.** (K)	**Pressure** (Pa)
Density	12000 kg/m^3	Solid	298.15	0
Modulus of Elasticity	110.316 GPa	Solid	0	
Poisson Ratio	0.39	Solid		
Thermal Expansion Coefficient	1.180×10^{-5} /K	Solid	298.15	

Electrical Properties **Conditions**

		Temp. (K)	Note
Electrical Resistivity	1.080×10^{-7} Ω-m	293.15	

Thermal Properties		Conditions	
		Temp. (K)	**Pressure** (Pa)
Melting Temperature	1828.05 K		101325
Boiling Temperature	3236.15 K		101325
Critical Temperature	7700 K		
Fusion Enthalpy	157.3 J/g	0	101325
Heat Capacity	244 J/kg-K	298.15	100000
Thermal Conductivity	71.8 W/m-K	300	101325



CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

Element Information: Uranium

Uranium

92	Atomic Number	92
U	Atomic Weight	238.0289
238.0289	Electron Config.	2-2-6-2-6-10-2-6-10-14-2-6-10-3-2-6-1-2

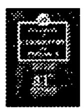
Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	**Temp.** (K)	**Pressure** (Pa)
Density	19100 kg/m^3	Solid	298.15	0
Modulus of Elasticity	165.474 GPa	Solid	0	
Poisson Ratio	0.23	Solid		
Thermal Expansion Coefficient	1.390×10^{-5} /K	Solid	298.15	

Electrical Properties		Conditions

		Temp. (K)	Note
Electrical Resistivity	3.000×10^{-7} Ω-m		chrystallographic average

Thermal Properties		**Conditions** Temp. (K)	**Conditions** Pressure (Pa)
Melting Temperature	1408.15 K		101325
Boiling Temperature	4404.15 K		101325
Critical Temperature	12500 K		
Fusion Enthalpy	38.4 J/g	0	101325
Heat Capacity	116 J/kg-K	298.15	100000
Thermal Conductivity	27.6 W/m-K	300	101325


CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

Element Information: Calcium

Calcium

20
Ca
40.078

Atomic Number	20
Atomic Weight	40.078
Electron Config.	2-2-6-2-6-0-2

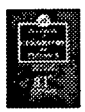
Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		**Conditions**		
		Phase	**Temp.** (K)	**Pressure** (Pa)
Density	1540 kg/m^3	Solid	298.15	0
Modulus of Elasticity	27.579 GPa	Solid	0	
Poisson Ratio	0.31	Solid		
Thermal Expansion Coefficient	2.230×10^{-5} /K	Solid	298.15	

Electrical Properties **Conditions**

		Temp. (K)	N te
Electrical Resistivity	3.910×10^{-8} Ω-m	273.15	

Thermal Properties		Conditions	
		Temp. (K)	**Pressure** (Pa)
Melting Temperature	1115.15 K		101325
Boiling Temperature	1757.15 K		101325
Critical Temperature	4300 K		
Fusion Enthalpy	213 J/g	0	101325
Heat Capacity	647 J/kg-K	298.15 more...	100000
Thermal Conductivity	200 W/m-K	300	101325



CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

Element Information: Va

Vanadium

23 V 50.9415		
	Atomic Number	23
	Atomic Weight	50.9415
	Electron Config.	2-2-6-2-6-3-2

Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	Temp. (K)	Pres
Density	6000 kg/m^3	Solid	298.15	
Modulus of Elasticity	131 GPa	Solid	0	
Poisson Ratio	0.37	Solid		
Thermal Expansion Coefficient	8.400×10^{-6} /K	Solid	298.15	

Electrical Properties		Conditi
		Temp. (K)
Electrical Resistivity	2.540×10^{-7} Ω-m	293.15

Thermal Properties		Conditions	
		Temp. (K)	Press
Melting Temperature	2183.15 K		10
Boiling Temperature	3680.15 K		10
Critical Temperature	11300 K		
Fusion Enthalpy	422 J/g	0	10
Heat Capacity	489 J/kg-K	298.15 more...	10
Thermal Conductivity	30.7 W/m-K	300	10

Download a Palm version of eFunda's periodic table!

CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

About Us Tell a Friend Suggestion Privacy Disclaimer Contac

<

efunda
engineering fundamentals

Element Information: Ta

Materials Home
Pure Elements
Periodic Table
Element List
by Name
by Symbol
by Atomic Number
by Atomic Weight
Element Information
Resources
Bibliography

Login

Tantalum

73 Ta 180.9479	Atomic Number	73
	Atomic Weight	180.9479
	Electron Config.	2-2-6-2-6-10-2-6-10-14-2-6-3-0-2

Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	Temp. (K)	Pres
Density	16400 kg/m^3	Solid	298.15	
Modulus of Elasticity	186.159 GPa	Solid	293.15	
Poisson Ratio	0.34	Solid		
Thermal Expansion Coefficient	6.300×10^{-6} /K	Solid	298.15	

Electrical Properties		Conditi
		Temp. (K)
Electrical Resistivity	1.245×10^{-7} Ω-m	298.15

Thermal Properties		Conditions	
		Temp. (K)	Press
Melting Temperature	3290.15 K		10
Boiling Temperature	5731.15 K		10
Critical Temperature	16500 K		
Fusion Enthalpy	202.1 J/g	0	10
Heat Capacity	140 J/kg-K	298.15 more...	10
Thermal Conductivity	57.5 W/m-K	300	10

CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

Niobium

41 **Nb** 92.90638	Atomic Number	41
	Atomic Weight	92.90638
	Electron Config.	2-2-6-2-6-10-2-6-4-0-1

Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	Temp. (K)	Pres
Density	8570 kg/m^3	Solid	298.15	
Poisson Ratio	0.4	Solid		
Thermal Expansion Coefficient	7.300×10^{-6} /K	Solid	298.15	

Electrical Properties		Conditi
		Temp. (K)
Electrical Resistivity	1.250×10^{-7} Ω-m	273.15

Thermal Properties		Conditions	
		Temp. (K)	Pressu
Melting Temperature	2750.15 K		101
Boiling Temperature	5017.15 K		101
Critical Temperature	12500 K		
Fusion Enthalpy	323 J/g	0	101
Heat Capacity	265 J/kg-K	298.15	100
Thermal Conductivity	53.7 W/m-K	300	101

CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

Element Information: B

Beryllium

4 **Be** 9.012182		
	Atomic Number	4
	Atomic Weight	9.012182
	Electron Config.	2-2

Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	Temp. (K)	Pres
Density	1850 kg/m^3	Solid	298.15	
Modulus of Elasticity	289.58 GPa	Solid	0	
Thermal Expansion Coefficient	1.130×10^{-5} /K	Solid	298.15	

Electrical Properties		Condition	
		Temp. (K)	
Electrical Resistivity	4.000×10^{-8} Ω-m	293.15	a

Table 6.1.9 Basic Properties of Several Metals
(Staff contribution)*

Material	Density,† g/cm^3	Coefficient of linear thermal expansion,‡ in/(in · °F) × 10^{-6}	Thermal conductivity, Btu/(h · ft · °F)	Specific heat,‡ Btu/(lb · °F)	Approx melting temp, °F	Modulus of elasticity, $lb/in^2 \times 10^6$	Poisson's ratio	Yield stress, $lb/in^2 \times 10^3$	Ultimate stress, $lb/in^2 \times 10^3$	Elongation, %
Aluminum 2024-T3	2.77	12.6	110	0.23	940	10.6	0.33	50	70	18
Aluminum 6061-T6	2.70	13.5	90	0.23	1,080	10.6	0.33	40	45	17
Aluminum 7079-T6	2.74	13.7	70	0.23	900	10.4	0.33	68	78	14
Beryllium, QMV	1.85	6.4–10.2	85	0.45	2,340	40–44	0.024–0.030	27–38	33–51	1–3.5
Copper, pure	8.90	9.2	227	0.092	1,980	17.0	0.32		See "Metals Handbook"	
Gold, pure	19.32		172	0.031	1,950	10.8	0.42		18	30
Lead, pure	11.34	29.3	21.4	0.031	620	2.0	0.40–0.45	1.3	2.6	20–50
Magnesium AZ31B-H24 (sheet)	1.77	14.5	55	0.25	1,100	6.5	0.35	22	37	15
Magnesium HK31A-H24	1.79	14.0	66	0.13	1,100	6.4	0.35	29	37	8
Molybdenum, wrought	10.3	3.0	83	0.07	4,730	40.0	0.32	80	120–200	Small
Nickel, pure	8.9	7.2	53	0.11	2,650	32.0	0.31§		See "Metals Handbook"	
Platinum	21.45	5.0	40	0.031	3,217	21.3	0.39		20–24	35–40
Plutonium, alpha phase	19.0–19.7	30.0	4.8	0.034	1,184	14.0	0.15–0.21	40	60	Small
Silver, pure	10.5	11.0	241	0.056	1,760	10–11	0.37	8	18	48
Steel, AISI C1020 (hot-worked)	7.85	6.3	27	0.10	2,750	29–30	0.29	48	65	36
Steel, AISI 304 (sheet)	8.03	9.9	9.4	0.12	2,600	28	0.29	39	87	65
Tantalum	16.6	3.6	31	0.03	5,425	27.0	0.35		50–145	1–40
Thorium, induction melt	11.6	6.95	21.7	0.03	3,200	7–10	0.27	21	32	34
Titanium, B 120VCA (aged)	4.85	5.2	4.3	0.13	3,100	14.8	0.3	190	200	9
Tungsten	19.3	2.5	95	0.033	6,200	50	0.28		18–600	1–3
Uranium D-38	18.97	4.0–8.0	17	0.028	2,100	24	0.21	28	56	4

Room-temperature properties are given. For further information, consult the "Metals Handbook" or a manufacturer's publication.
* Compiled by Anders Lundberg, University of California, and reproduced by permission.
† To obtain the preferred density units, kg/m^3, multiply these values by 1,000.
‡ See also Tables 6.1.10 and 6.1.11.
§ At 25°C.

PHYSICAL PROPERTIES OF THE RARE EARTH METALS (continued)

Table 11
Room Temperature Elastic Moduli and Mechanical Properties

Rare earth metal	Elastic moduli (GPa)				Mechanical properties (MPa)				Recryst. temp. (°C)
	Young's (elastic) modulus	Shear modulus	Bulk modulus	Poisson's ratio	Yield strength 0.2% offset	Ultimate tensile strength	Uniform elongation (%)	Reduction in area (%)	
Sc	74.4	29.1	56.6	0.279	173[a]	255[a]	5.0[a]	8.0[a]	550
Y	63.5	25.6	41.2	0.243	42	129	34.0	—	550
αLa	36.6	14.3	27.9	0.280	126[a]	130	7.9[a]	—	300
βCe	—	—	—	—	86	138	—	24.0	—
γCe	33.6	13.5	21.5	0.24	28	117	22.0	30.0	325
αPr	37.3	14.8	28.8	0.281	73	147	15.4	67.0	400
αNd	41.4	16.3	31.8	0.281	71	164	25.0	72.0	400
αPm	46[b]	18[b]	33[b]	0.28[b]	—	—	—	—	400[b]
αSm	49.7	19.5	37.8	0.274	68	156	17.0	29.5	440
Eu	18.2	7.9	8.3	0.152	—	—	—	—	300
αGd	54.8	21.8	37.9	0.259	15	118	37.0	56.0	500
αTb	55.7	22.1	38.7	0.261	—	—	—	—	500
αDy	61.4	24.7	40.5	0.247	43	139	30.0	30.0	550
Ho	64.8	26.3	40.2	0.231	—	—	—	—	520
Er	69.9	28.3	44.4	0.237	60	136	11.5	11.9	520
Tm	74.0	30.5	44.5	0.213	—	—	—	—	600
βYb	23.9	9.9	30.5	0.207	7	58	43.0	92.0	300
Lu	68.6	27.2	47.6	0.261	—	—	—	—	600

Note: For additional information, see Scott, T., in *Handbook on the Physics and Chemistry of Rare Earths*, Vol. 1, Gschneidner, K.A., Jr. and Eyring, L., Eds., North-Holland Physics, Amsterdam, 1978, 591.

[a] Value is questionable.
[b] Estimated.

Element Information: Cerium

Materials Home
- **Pure Elements**
  - Periodic Table
  - Element List
    - by Name
    - by Symbol
    - by Atomic Number
    - by Atomic Weight
  - Element Information
- **Res urces**
  - Bibliography

Suggested Reading

Login

Home | Membership | Palm Store | Forum | Search Member | What's New | Calculators

Search All for Go

Materials Design Center Processes Units & Constants Formulas Mathematics

Download a Palm version of eFunda's periodic table!

Cerium

58
Ce
140.115

Atomic Number	58
Atomic Weight	140.115
Electron Config.	2-2-6-2-6-10-2-6-10-1-2-6-1-0-2

Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

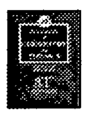
Mechanical Properties		Conditions		
		Phase	**Temp.** (K)	**Pressure** (Pa)
Density	8160 kg/m^3	Solid	298.15	0
Modulus of Elasticity	41.369 GPa	Solid	313.15	
Poisson Ratio	0.24	Solid		
Thermal Expansion Coefficient	5.200×10^{-6} /K	Solid	298.15	

Electrical Properties **Conditions**

		Temp. (K)	Note
Electrical Resistivity	7.500×10^{-7} Ω-m	298.15	

Thermal Properties		Conditions	
		Temp. (K)	Pressure (Pa)
Melting Temperature	1072.15 K		101325
Boiling Temperature	3697.15 K		101325
Critical Temperature	9750 K		
Fusion Enthalpy	39 J/g	0	101325
Heat Capacity	192 J/kg-K	298.15	100000
Thermal Conductivity	11.3 W/m-K	300	101325

Download a Palm version of eFunda's periodic table!



CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

Element Information: Barium

Barium

56
Ba
137.327

Atomic Number	56
Atomic Weight	137.327
Electron Config.	2-2-6-2-6-10-2-6-10-0-2-6-0-0-2

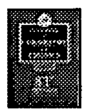
Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	**Temp.** (K)	**Pressure** (Pa)
Density	3620 kg/m^3	Solid	298.15	0
Thermal Expansion Coefficient	2.060×10^{-5} /K	Solid	298.15	

Thermal Properties		Conditions	
		Temp. (K)	**Pressure** (Pa)
Melting Temperature	1000.15 K		101325

Boiling Temperature	2170.15 K		101325
Critical Temperature	4450 K		
Fusion Enthalpy	52 J/g	0	101325
Vaporization Enthalpy	1019.46 J/g	0	101325
Heat Capacity	204 J/kg-K	298.15	100000
Thermal Conductivity	18.4 W/m-K	300	101325

Download a Palm version of eFunda's periodic table!



CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

Element Information: Chr

Chromium

24 Cr 51.9961		
	Atomic Number	24
	Atomic Weight	51.9961
	Electron Config.	2-2-6-2-6-5-1

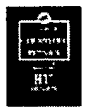
Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	Temp. (K)	Press
Density	7150 kg/m^3	Solid	298.15	
Modulus of Elasticity	248.211 GPa	Solid	0	
Poisson Ratio	0.31	Solid		
Thermal Expansion Coefficient	4.900×10^{-6} /K	Solid	298.15	

Electrical Properties		Conditior
		Temp. (K)
Electrical Resistivity	1.290×10^{-7} Ω-m	273.15

Thermal Properties		C nditi ns	
		Temp. (K)	Pressui
Melting Temperature	2180.15 K		1013
Boiling Temperature	2944.15 K		1013
Critical Temperature	5500 K		
Fusion Enthalpy	404 J/g	0	1013
Heat Capacity	449 J/kg-K	298.15 more...	1000
Thermal Conductivity	93.7 W/m-K	300 more...	1013

Download a Palm version of eFunda's periodic table!



CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

efunda
engineering fundamentals

Element Information: Pall

Palladium

46
Pd
106.42

Atomic Number	46
Atomic Weight	106.42
Electron Config.	2-2-6-2-6-10-2-6-10

Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	Temp. (K)	Press
Density	12000 kg/m^3	Solid	298.15	
Modulus of Elasticity	110.316 GPa	Solid	0	
Poisson Ratio	0.39	Solid		
Thermal Expansion Coefficient	1.180×10^{-5} /K	Solid	298.15	

Electrical Properties		Conditior
		Temp. (K)
Electrical Resistivity	1.080×10^{-7} Ω-m	293.15

Thermal Properties		Conditions	
		Temp. (K)	Pressur
Melting Temperature	1828.05 K		1013
Boiling Temperature	3236.15 K		1013
Critical Temperature	7700 K		
Fusion Enthalpy	157.3 J/g	0	1013
Heat Capacity	244 J/kg-K	298.15	1000
Thermal Conductivity	71.8 W/m-K	300	1013

Download a Palm version of eFunda's periodic table!


CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

Element Information: Ur

Uranium

92
U
238.0289

Atomic Number	92
Atomic Weight	238.0289
Electron Config.	2-2-6-2-6-10-2-6-10-14-2-6-10-3-2-6-1-.

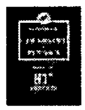
Electron configuration order: *1s-2s-2p-3s-3p-3d-4s-4p-4d-4f-5s-5p-5d-5f-6s-6p-6d-7s*

Mechanical Properties		Conditions		
		Phase	Temp. (K)	Press
Density	19100 kg/m^3	Solid	298.15	
Modulus of Elasticity	165.474 GPa	Solid	0	
Poisson Ratio	0.23	Solid		
Thermal Expansion Coefficient	1.390×10^{-5} /K	Solid	298.15	

Electrical Properties		Conditions	
		Temp. (K)	Note
Electrical Resistivity	3.000×10^{-7} Ω-m		chrystallographic a

Thermal Properties		Conditions	
		Temp. (K)	Pressur
Melting Temperature	1408.15 K		1013:
Boiling Temperature	4404.15 K		1013:
Critical Temperature	12500 K		
Fusion Enthalpy	38.4 J/g	0	1013:
Heat Capacity	116 J/kg-K	298.15	1000(
Thermal Conductivity	27.6 W/m-K	300	1013:

Download a Palm version of eFunda's periodic table!



CRC Hankbook of Chemistry and Physics , 81th ed., *by Lide, D.R. (ed.)*

About Us Tell a Friend Suggestion Privacy Disclaimer Contact

Click here to find out more!

REFERENCES

1. Lorman, Willianam R., *Enginring Properties of Shotcrete,* NCEL Technical Reporort R429 with A(Addendum. Feort prepared by U.S. Naval Civil Engineering Laborara-tories, Port HuHuenema, Calirnia, published by American Concrete Institute, Detroit;it, Michigan (196868).
2. Bank, Robert F.F. and Kenne, Henry L., *Technology of Cement and Concrete,* Vol. 1 1, pp. 265-271, J(John S. Wileynd Sons, Inc., New York (1955).
3. Troxell, George le Earl, David,armer G. and Kelly, Joe W., *Compositions and Propertiesies of Concrete,* S(Second Editic pp. 60-92, McGraw-Hill, New York (1956).

PART B

SILICATE MMONOLITHICS, GUNNED SODIUM SILICATES

obert L. Trinklein

Hœshoe Bend, Arkansas

Silicate corrosision-resistar cements as described in other sections of this is book are also availailable as gure grades. The sodium silicate systems include the ie two-part chemical I setting typ and the one-part modified system. The gunite :e grades are applied I by pneumic gunning systems such as the Allentown, the ie Reed, or similar manachines whh mix dry powder and liquid at the nozzle of the ie gun. This of coursese, necessitas the formulation of coarser aggregate mixes that it set much more rapioidly than mtar or castable silicates.

In guniting theiese mixes its generaly recommended that they be predamp-o-ened to reduce thene rebound ss and dusting. This is done by placing the dry y powder of the mix x either in anixer or through a conveyor type machine loader er where it is dampenened with a all amount of liquid. The dampened material is is then mixed with mmore liquid the nozzle of the gun and impacted on the sur-r-face to be lined. UsUsually the ozzle is kept 3 to 4 feet from the surface and is is moved rythmically y in a serieof loops 6 to 9 inches high and 18 to 24 inches es wide as the materiaial is impacd perpendicularly on to the surface. The freshly y impacted material s should hava smooth shiny surface. A sandy granular surface :e indicates that the n mix is toodry, whereas a rippling appearance indicates that it the material is too w wet.

These monolithithic gunite ings usually are single, large units, with or with-n-out expansion jointnts. They arapplied in thicknesses from ½ inch up to several al inches depending on the servi requirements. Linings one inch or more in thick-<-ness should be ancnchored witlstuds or with wire mesh that is adequately pro-o-tected. The anchorbring system necessary to retain the lining in contact with the ie

surface of the subsbstrate durir application, curing, andıd service, anto distributete stresses to control ‹l cure-crackij.

Gunited monıınolithic soam silicates have been ı used for nny years asas linings for stacks, s, tanks, chineys, sewers, and otherer equipmer. They resistist most acids (excepıpt hydroflu ic and acid fluoride saltılts), moistuıand temperer-ature up to 1500°F°F. Perhapsıe following advantages s have been sponsible foror their successful usese over the pt years:

(1) Monolithihic gunited ıings can be applied verertically, hoızontally, and overhrhead withα the need for complex x forms, suıorts, or scaffolds. s.

(2) Curved orır irregular sfaces can be covered uniniformly.

(3) Gunned sı sodium silice monolithic linings disiplay a tackess that improves ts the bondinand densification of the le liner.

(4) They do ɒ not give oftoxic fumes or odors duuring mixin applica-tion, and d setting.

Gunned monoıolithic silicas of all types have somene limitatiorthat must bebe considered before e they canıe successfully used. ThThey, like alcementitiousus materials, are infleflexible andınd toward brittleness. T The moduli of elasticityty ranges from 10^4 to:o 10^6 psi anflexural strength from 5C500 to 2,000si dependingng upon the densificacation and fmulation. Similarly, tenensile strengı ranges fromm 150 to 400 psi, aıand compreive strengths from 1,50500 to 4,00psi. Thermaıal properties such as ıs coefficientf thermal expansion shoıould be matıed to that oıof the substrate; howwever, wheıthis is not possible, a r membrane required bebe-tween the lining arand the subrate to provide a slip-plalane and prent crackingıg. In continuously wwet conditics a membrane should alalso be usedecause of thehe high diffusion ratete and absption of silicate materiarials. The thmal conducuc-tivity of a gunned d sodium silate lining is lower than ı that of ste or concretete. This is usually advdvantageouss the lower temperature e on the sukrate reduceses corrosion and therermal movemt.

In general, sosodium silica gunned linings have spspecific andnique advanan-tages as corrosion-n-resistant ceents; however, they musıst be carefu formulatedd, specified, and applplied to makthem cost effective.

Typical Phʰhysical Propties of Gunned Sodium h Silicate Marials

Compressiveve strength	4,500 pspsi
Tensile strerength	300 psi si
Cure shrinkıkage	0.75%
Absorptionın	1.25%
Coefficient ıt of thermalxpansion	11.8 x x 10^{-6} in/in/
Density	140 lb/f/ft^3
Flexural strtrength	240 psi si
Modulus ofof elasticity	2.0 x 1 10^4 psi
Thermal coıonductivity	3.7–4.8.8 Btu/ft^2/hıF/in

PART C
GUNNED POTASSIUM SILICATE

Walter Lee Sheppard, Jr.
C.R.M., Incorporated
Hertown, Pennsylvania

HISTORY AND LIMITATIONS

Air spraying of ceramic coatings began well over half a century ago, starting with hydraulic cement formations. The procedures followed and the equipment used have undergone considerable refinement, but only minor changes, over the years. They are well expounded in Mr. Smith's section, and so will not be repeated here. At some time about mid-century, experiments were run using this same procedure to apply sodium silicate coatings, primarily as a lining for the interior of stacks and chimneys venting acid-laden flue gases, and this type of lining is now frequently also seen in high temperature ducting and in many other applications when top temperatures are outside the economical limits of organic linings. Mr. Trinklein's short paper gives the basic information on such current sodium silicate usage.

The three most important limitations of gunned silicate linings are probably (in this order) rather high absorption, cure shrinkage, and swelling or growth—in particular sulfation-hydration reactions. Like hydraulic mortars, all silicates require water in the mix, both for application and for the chemical reaction that "cures" or hardens the material. When the water evaporates, it leaves a porous structure behind. By careful formulation of the mix and careful grading of the particle size, the manufacturer can reduce the size of these voids and so reduce the porosity, but he can never eliminate it totally. Therefore, over a period of time, moisture in contact gas and water that condenses or collects on its surface will absorb into these voids and so eventually penetrate through the lining and reach the substrate, carrying with it any chemicals (whether acid or not) that are dissolved in the fluid.

As gunned lining "cures" or hardens due to chemical action, it undergoes a volume change. Cure shrinkage occurs in all concrete and other hydraulic mortars, but is higher in silicates. The shrinkage creates random stress in the material as it tries to pull itself together. If no provision is made for cure shrinkage, both cast concrete and gunned linings can break up. To prevent concrete floors from breaking up, they are reinforced with rod or mesh. This same principle is followed with gunned linings.

The third limitation—that of the sulfation-hydration growth chemical reactions—is peculiar to all *sodium* silicate compositions and has been discussed elsewhere in this volume. Those desiring more details may find references for it in the Bibliography at the end of this chapter. The only proven way to eliminate it totally is to eliminate the sodium. This can be done by changing from a sodium

silicate composition to a potassium silicate one, and to employ a hardener (a "catalyst") that contains no sodium.

It should not be assumed, however, that the total replacement of sodium by potassium will also eliminate all hydration growth reactions. Potassium may form complex salts called alums in combination with a few other basic radicals—including particularly magnesium, iron and aluminum, combined with sulfuric acid. These alums can pick up molecular water of crystallization and grow. So while the substitution of potassium silicate for sodium will eliminate the great majority of growth problems, it may not eliminate all, and the designer should bear this in mind in his study of the anticipated environmental conditions of the installation.

Although gunned sodium silicate mixes have been continuously available since this type of lining was first investigated, no real effort seems to have been made to produce a gunned potassium silicate until fairly recently, due perhaps to difficulty in getting the available mixes to gun in a satisfactory manner, without excessive sag and rebound. A gunned 2-component potassium silicate employing a sodium silicofluoride hardener became available about 1980.

After an extended period of research, the first all-potassium (single component) mix became available in 1978, largely through the combined efforts of Norman Huxley and Ray Lea, and in 1980, U.S. Patent 4,227,932 was granted on the design.

Hydraulic mortars (portland and calcium aluminate cements), when placed by gun, are usually predamped with a small amount of water, and the balance of the water is added at the nozzle. The gunned all-potassium material is also a single component, containing spray-dried potassium silicate and silica powder to which water is added.

COMPOSITION AND PROPERTIES

The dry all-potassium silicate gunite formulation contains only dried potassium silicate, crushed and graded silica, and the curing or hardening agent—which, in this case, is a specially formulated and patented condensed aluminum polyphosphate. (For further details see *Chemically Resistant Masonry*, p 181, listed in the Bibliography.) There are no other materials whatsoever in the formulation, and in application, it is mixed only with clean, neutral potable water.

Typical physical properties after placement are:

Compressive strength, 28 days (ASTM C-579)	3,100 psi (217 kp/cm^2)
Toluene absorption	2.9%
Wet gunned density	138 lb/ft^3 (2,208 kg/m^3)
Cured gunned density	120 lb/ft^3 (1,923 kg/m^3)
Bond to steel	160 psi (11.2 kp/cm^3)
Tensile strength, 14 days	425 psi (29.7 kp/cm^2)
Flexural strength, 14 day	730 psi (51 kp/cm^2)
Linear shrinkage	0.005 in/in unrestrained

Thermal conduductivity:	
at 280°F	4.4 Btu/ft^2/hr/°F/in (0.63 W/m/°C)
at 620°F	5.0 Btu/ft^2/hr/°F/in (0.72 W/m/°C)
at 1000°F	5.5 Btu/ft^2/hr/°F/in (0.79 W/m/°C)
Modulus of ela:lasticity	1.57×10^6 psi (1.1×10^5 kp/cm^2)
pH resistance r range	0 to 9
Maximum servrvice temperure	1650°F (900°C)
Coefficient of f thermal exansion	7.0×10^{-6} in/in/°F (12.6×10^{-6} m/m/°C)

All data has b been basedn specimens resulting from actual gunning per-r-formed by a qualiility gunite plicator. Water, air, and material feed pressureses were controlled. WWater and gning mix temperature were at ambient. Gunningng was performed onn flat, vertal panels. ASTM procedures, where applicableJe, were used for deteterminationdata. All data are subject to reasonable deviationn and should not, ththerefore, beed for specification purposes.

Actual field gugunning contions may vary and, therefore, yield different re-e-sults. These data a are presentonly as ideals and for comparing this mix withth another under identntical condins.

Because it is a a single dryomponent material, it can be stored in any con-n-venient ambient ststorage temrature as long as it is kept dry. Winter freezingng temperatures have e no effect its storage life.

CURING

The mix takeses a rapid s after application (surface is hard in 15 minuteses after gunning), anand quicklylevelops strength and chemical resistance. It isis recommended, hovowever, thait be allowed to cure for seven days undisturbeded at 70°F prior to plplacing in seice, and protected from the weather for at leastst the first two days.s. If it is deed to place the unit in service faster, this may bebe accomplished *afterer* the first 2 hours ambient cure, by heating at not more thanan 50°F (28°C) per hoour to the orking temperature, except that when the temper-r-ature of 250°F (12121°C) is reaed, the temperature must be held at that level foror six hours before raiaising it furter.

APPLICATION

Application shshould be mde with the substrate in the temperature range ofof 60° to 90°F (in noo case at a mperature below 50°F) and weather in the samene range, and should fl follow norl gunite procedures. The manufacturer provides a a detailed instructioron guide forhe benefit not only of the applicator, but also ofof the client, whose ir inspectors wl monitor the installation. Proper surface prepara-a-tion is obviously a a necessity.An anchoring and/or reinforcing system is alwaysys recommended. Steteel should l free of oil, grease, mill scale, rust, etc., with noo holes or voids and d all welds sooth and continuous, and sandblasted to a "com-n-mercial" finish (SSSPC#6). Esting brickwork should be brush sandblasted toto remove all surface e contaminaon and loose material. Small deep holes and voidsds may require prepatatchings.

COMMERCIAL METALS AND ALLOYS

This table gives typical values of mechanical, thermal, and electrical properties of several common commercial metals and alloys. Values refer to ambient temperature (0 to 25°C). All values should be regarded as typical, since these properties are dependent on the particular type of alloy, heat treatment, and other factors. Values for individual specimens can vary widely.

REFERENCES

1. *ASM Metals Reference Book, Second Edition*, American Society for Metals, Metals Park, OH, 1983.
2. Lynch, C. T., *CRC Practical Handbook of Materials Science*, CRC Press, Boca Raton, FL, 1989.
3. Shackelford, J. F., and Alexander, W., *CRC Materials Science and Engineering Handbook*, CRC Press, Boca Raton, FL, 1991.

Common name	Thermal conductivity W/cm K	Density g/cm³	Coeff. of linear expansion 10^{-6}/°C	Electrical resistivity μΩ cm	Modulus of elasticity GPa	Tensile strength MPa	Approx. melting point °C
Ingot iron	0.7	7.86	11.7	9.7	205	-	1540
Plain carbon steel AISI-SAE 1020	0.52	7.86	11.7	18	205	450	1515
Stainless steel type 304	0.15	7.9	17.3	72	195	550	1425
Cast gray iron	0.47	7.2	10.5	67	90	180	1175
Malleable iron		7.3	12	30	170	345	1230
Hastelloy C	0.12	8.94	11.3	125	200	780	1350
Inconel	0.15	8.25	11.5	103	200	800	1370
Aluminum alloy 3003, rolled	1.9	2.73	23.2	3.7	70	110	650
Aluminum alloy 2014, annealed	1.9	2.8	23.0	3.4	70	185	650
Aluminum alloy 360	1.5	2.64	21.0	7.5	70	325	565
Copper, electrolytic (ETP)	3.9	8.94	16.5	1.7	120	300	1080
Yellow brass (high brass)	1.2	8.47	20.3	6.4	100	300-800	930
Aluminum bronze	0.7	7.8	16.4	12	120	400-600	1050
Beryllium copper 25	0.8	8.23	17.8	7	130	500-1400	925
Cupronickel 30%	0.3	8.94	16.2		150	400-600	1200
Red brass, 85%	1.6	8.75	18.7	11	90	300-700	1000
Chemical lead	0.35	11.34	29.3	21	13	17	327
Antimonial lead (hard lead)	0.3	10.9	26.5	23	20	47	290
Solder 50-50	0.5	8.89	23.4	15	-	42	215
Magnesium alloy AZ31B	1.0	1.77	26	9	45	260	620
Monel	0.3	8.84	14.0	58	180	545	1330
Nickel (commercial)	0.9	8.89	13.3	10	200	460	1440
Cupronickel 55-45 (constantan)	0.2	8.9	18.8	49	160	-	1260
Titanium (commercial)	1.8	4.5	8.5	43	110	330-500	1670
Zinc (commercial)	1.1	7.14	32.5	6	-	130	419
Zirconium (commercial)	0.2	6.5	5.85	41	95	450	1855

Elastic essence ticket of metal

T he Table of Modulus of Elasticity about Metal

Gold inside Metal		Bulk modulus K [kgf/cm ^{2}]	Elastic modulus E [kgf/cm ^{2}]	Modulus of transverse elasticity G [kgf/cm ^{2}]	phu With song rain ν
Li	Lithium	1.39 X 10 ^{5}	1.17 X 10 ^{5}	0.43 X 10 ^{5}	0.36
Na	Sodium	0.83 X 10 ^{2}	0.91 X 10 ^{2}	0.35 X 10 ^{2}	0.32
K	Potassium	0.41 X 10 ^{2}	0.36 X 10 ^{2}	0.13 X 10 ^{2}	0.35
Be	Beryllium	1.28 X 10 ^{3}	3.16 X 10 ^{3}	1.50 X 10 ^{3}	0.05
Mg	Magnesium	3.39 X 10 ^{2}	4.52 X 10 ^{2}	1.77 X 10 ^{2}	0.28
Al	Aluminum	7.46 X 10 ^{2}	7.19 X 10 ^{2}	2.72 X 10 ^{2}	0.34
Ti	Titanium	1.26 X 10 ^{3}	1.08 X 10 ^{3}	4.05 X 10 ^{2}	0.34
Zr	Zirconium	9.15 X 10 ^{2}	9.75 X 10 ^{2}	3.68 X 10 ^{2}	0.33
Hf	Hafnium	1.12 X 10 ^{3}	1.41 X 10 ^{3}	5.40 X 10 ^{2}	0.30
V	Vanadium	1.65 X 10 ^{3}	1.30 X 10 ^{3}	4.76 X 10 ^{2}	0.36
Nb	Niobium	1.67 X 10 ^{3}	1.06 X 10 ^{3}	3.73 X 10 ^{2}	0.38
Ta	Tantalum	2.11 X 10 ^{3}	1.88 X 10 ^{3}	7.00 X 10 ^{2}	0.35
Cr	Chromium	1.94 X 10 ^{3}	2.40 X 10 ^{3}	9.00 X 10 ^{2}	0.30
Mo	Molybdenum	2.80 X 10 ^{3}	3.47 X 10 ^{3}	1.22 X 10 ^{3}	0.30
W	Tungsten	3.19 X 10 ^{3}	3.96 X 10 ^{3}	1.51 X 10 ^{3}	0.29
Mn	Manganese	1.27 X 10 ^{3}	2.02 X 10 ^{3}	7.80 X 10 ^{2}	0.24
Fe	Iron	1.72 X 10 ^{3}	2.17 X 10 ^{3}	8.47 X 10 ^{2}	0.28
Co	Cobalt	1.87 X 10 ^{3}	2.04 X 10 ^{3}	7.63 X 10 ^{2}	0.31
Ni	Nickel	1.87 X 10 ^{3}	2.05 X 10 ^{3}	7.85 X 10 ^{2}	0.31
Cu	Copper	1.40 X 10 ^{3}	1.25 X 10 ^{3}	4.64 X 10 ^{2}	0.34
Ag	Silver	1.02 X 10 ^{3}	8.05 X 10 ^{2}	2.94 X 10 ^{2}	0.38
Au	Gold	1.75 X 10 ^{3}	8.02 X 10 ^{2}	2.82 X 10 ^{2}	0.42
Zn	Zinc	6.17 X 10 ^{2}	9.40 X 10 ^{2}	3.79 X 10 ^{2}	0.29
CD	Cadmium	4.85 X 10 ^{2}	6.35 X 10 ^{2}	2.46 X 10 ^{2}	0.30
In	Indium	4.45 X 10 ^{2}	1.07 X 10 ^{2}	0.38 X 10 ^{2}	0.46
Tl	Thallium	3.71 X 10 ^{2}	0.81 X 10 ^{2}	0.28 X 10 ^{2}	0.46
Si	Silicon	3.22 X 10 ^{3}	1.15 X 10 ^{3}	4.05 X 10 ^{2}	0.44
General Electric	Germanium	7.11 X 10 ^{2}	1.01 X 10 ^{3}	4.00 X 10 ^{2}	0.28
Sn	Tin	5.20 X 10 ^{2}	5.54 X 10 ^{2}	2.08 X 10 ^{2}	0.33
Pb	Lead	4.22 X 10 ^{2}	1.66 X 10 ^{2}	0.57 X 10 ^{2}	0.44
Sb	Antimony	4.00 X 10 ^{2}	5.60 X 10 ^{2}	2.04 X 10 ^{2}	0.28
Bi	Bismuth	3.60 X 10 ^{2}	3.48 X 10 ^{2}	1.31 X 10 ^{2}	0.33

Reference : W. K ö ster and H. Franz : Metallurgical Review, 6 (1961)